

Technologies for Power Generation from Wind

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Abstract- Achieving sustainable development is a target that is now widely seen as important to worldwide public opinion. In this regard, the utilization of renewable energy resources, such as solar, geothermal, and wind energy, appears to be one of the most efficient and effective ways in achieving this target. Recently, wind power as a potential energy has grown at an impressive rate in India. The present paper deals with the technical details involved in the generation of power through wind energy. It discusses the factors responsible for generation of wind power and the limitations of the generator. Various schemes used for production of electricity using wind power are also discussed. The paper also gives insight into energy storage methods, safety precautions and site selection criteria.

Keywords-Wind power; renewable energy

I. INTRODUCTION

Energy is the primary and most universal measure of all kinds of work by human beings and nature. Everything that happens in the world is the expression of flow of energy in one of its forms Energy is an important input in all sectors of a country's economy. The standard of living is directly related to per capita energy consumption.

The demand for energy is increasing at an exponential rate due to the exponential growth of world population. The combined effect of the widespread depletion of fossil fuels and the gradually emerging consciousness about environmental degradation has given priority to the use of conventional and renewable alternative energy sources such as solar, wind and solar-hydrogen energies [1]. The rapid development in wind energy technology has made it an alternative to conventional energy systems in recent years. Parallel to this development, wind energy systems have made a significant contribution to daily life in developing countries, where one-third of the world's people live without electricity [2, 3].

Wind results from air in motion due to pressure gradient that is caused by the solar energy irradiating the earth. Wind possesses energy by virtue of its motion .Any device capable of slowing down the mass of moving air can extract part of the energy and convert into useful work. Following factors control the output of wind energy converter [4, 5 and 6]:

- The wind speed
- Cross-section of the windswept by rotor
- Conversion efficiently of rotor
- Generator
- Transmission system

Theoretically it is possible to get 100% efficiency by halting and preventing the passage of air through the rotor. However, a rotor is able to decelerate the air column only to one third of its free velocity.

A 100% efficient wind generator is able to convert maximum up to 60% of the available energy in wind into mechanical energy. In addition to this, losses incurred in the generator or pump decrease the overall efficiency of power generation to 35%.

II. PRINCIPLE OF ENERGY CONVERSION

Wind mills or turbines works on the principle of converting kinetic energy of the wind in to mechanical energy.

$$\text{Power available from wind mill} = \frac{1}{2} \rho A V^3$$

Where, ρ – air density = 1.225 Kg. / m³ at sea level.(changes by 10-15% due to temperature and pressure variations)

$$A - \text{area swept by windmill rotor} = \pi D^2 \text{ sq-m. } (D - \text{diameter})$$

$$V - \text{wind speed m/sec.}$$

Air density, which linearly affects the power output at a given speed, is a function of altitude, temperature and barometric pressure. Variation in temperature and pressure can affect air density up to 10 % in either direction. Warm climate reduces air density. This equation tells us that maximum power available depends on both, the wind speed and the rotor diameter (fig 1). The combined effects of wind speed and rotor diameter can be observed by the following graph [7]:

This graph indicates that wind machines should have large rotors and should be located in areas of high wind speeds. Practically, wind turbines are able to convert only a fraction of available wind power into useful power. As the free wind stream passes through the rotor, it transfers some of its energy to the rotor and its speed decreases to a minimum in the rotor wake. After some distance from the rotor wind stream regains its speed from the surrounding air. We can also observe drop in pressure as the wind stream passes through the rotor (fig 2). Finally air speed and pressure increases to ambient atmospheric condition. This is illustrated in the following graphs [7, 8]

Site Selection

Following factors are to be considered for selection of good site for wind power generation [7, 8 and 9]:

- High annual wind speed.

- No tall obstructions for a radius of 3 Km.
- Open plain or open shore
- Top of a smooth, well rounded hill with gentle slopes
- Mountain gap which produces wind funneling.

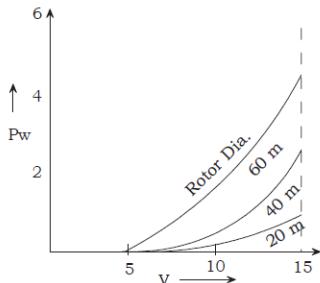


Fig 1. Dependances of wind energy conversion power on wind speed and rotor diameter

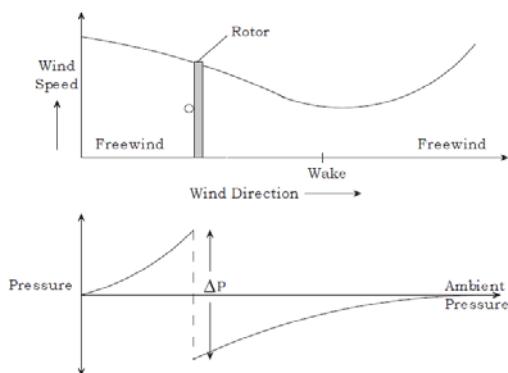


Fig 2 Wind speed and pressure variation

III. GENERATING SYSTEMS

Wind - electric conversion system consists of the following components :-

Wind Turbine(WT)- Converts wind energy into rotational(mechanical) energy

Gear system and coupling (G/C)- It steps up the speed and transmits it to the generator rotor

Generator(G)- Converts rotational energy into electrical energy.

Types of generators used

- For Small P.M.type d.c. generators rating systems
- Medium P.M.type d.c. generators rating systems
- Large Induction generators (3-phase) rating systems
- Controller(C)-Senses wind direction, wind speed generator output and yaw motor gear- The area of the wind stream swept by the wind turbine is maximum when blades face into the wind. Alignment of the blade angle with respect to the wind direction to get maximum wind energy can be achieved with the help of yaw control that rotates wind turbine about the vertical axis.
- temperature and initiates appropriate control signals to take control action.

In smaller wind turbines, yaw action is controlled by tail vane whereas, in larger turbines, it is operated by servomechanism (fig 3).

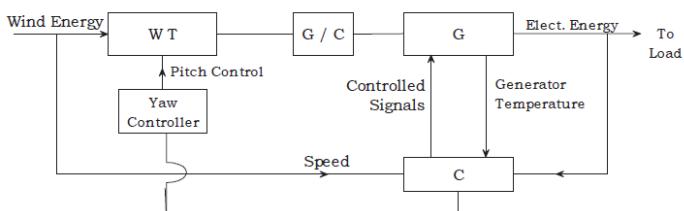


Fig 3. Wind energy conversion system

Apart from the above components, protective schemes for excessive temperature rise of generator, against electrical faults and turbulent wind conditions are also provided in the system. Practically, Wind power generating system ratings are divided into three groups:

- Small up to 1KW
- Medium 1 KW to 50 KW
- Large 200KW to Megawatts

IV. SCHEMES FOR WIND POWER GENERATION

Based on the speed and frequency, generally following schemes are identified:

A. CSCFS (Constant Speed Constant Frequency Scheme)

Constant speed drives are used for large generators that feed the generated power to the grid. Commonly synchronous generators or induction generators are used for power generation (fig 4).

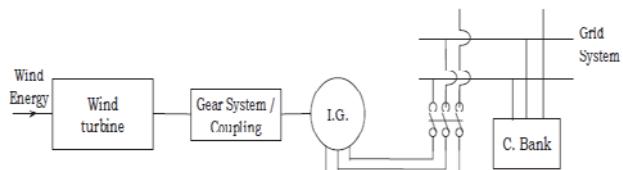


Fig. 4. Constant Speed Constant Frequency Scheme

(*I.G.: Induction generator, C. Bank: Capacitor bank)

If the stator of an induction machine is connected to the power grid and if the rotor is driven above synchronous speed, N_s , the machine delivers a constant line frequency ($f = PN_s/120$) power to the grid. The slip of the generators is between 0 and 0.05. The torque of the machine should not exceed max. torque to prevent 'run away' (speed continues to increase unchecked). Compared to synchronous generator, Induction generators are preferred because they are simpler, economical, easier to

operate, control and maintain and have no synchronization problem. However, Capacitors have to be used to avoid reactive volt ampere burden on the grid.

B. DSCFS (Dual Speed Constant Frequency Scheme)

In this scheme a dual speed wind turbine is coupled to double winding Induction generator that is specially fabricated with 2 stator windings wound with different number of poles P1& P2 ($P_1 > P_2$). When wind speed is *low*, winding with P1 poles gets connected and power is generated with grid frequency. Similarly, when wind speed is *high*, winding with P2 poles gets connected and feed the power to grid at the same frequency. It is Important to note that the difference in speed should be small. Reactive power required by the Induction Generator can be supplied by installing the Capacitor bank (fig 5).

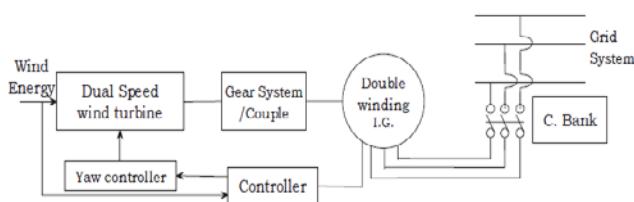


Fig 5. Dual speed constant frequency scheme

C. VSCFS (Variable speed constant frequency scheme)

In this scheme output of three phase alternator (synchronous generator) is rectified by bridge rectifier. The DC output is transmitted through DC transmission lines and then converted back to AC using synchronous inverters and fed to grid system (fig 6).

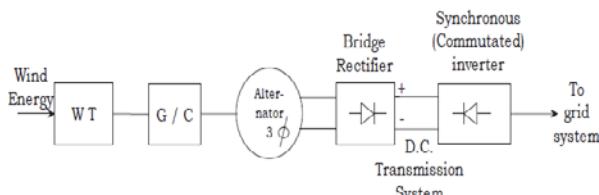


Fig 6. Variable speed constant frequency scheme

This scheme, involving small wind generators is commonly used in autonomous applications such as street lighting. Due to variable speed operation, it yields higher power for both low and high wind speeds. Both horizontal axis and vertical axis turbines are suitable.

D. Variable speed constant frequency with double output (VSCF with DO)

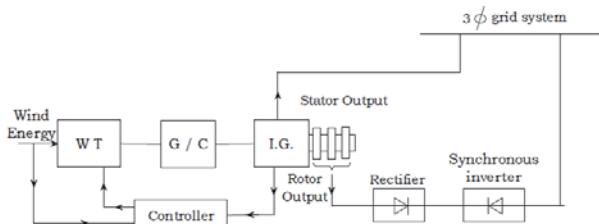


Fig. 7. Variable speed constant frequency with double output

In this scheme, to increase the power generating capacity of the system, squirrel cage induction generators are replaced by slip ring Induction generator. Rotor power output at slip frequency is converted to line frequency power using rectifier. Output power is obtained both from stator and rotor. Rotor output power increases with increase in slip and speeds. Therefore, operating speed range is N_s to $2N_s$ i.e. slip ranging from 0 to 1 (fig 7).

E. (VSVFS) Variable speed variable frequency schemes

This scheme is suitable for loads that are frequency insensitive such as heating load.

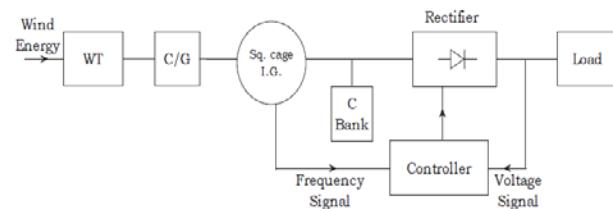


Fig 8. Variable speed variable frequency schemes

Depending upon the wind speed, squirrel cage Induction Generator generates power at variable frequency. Such generators are excited by Capacitor-bank. The magnitude and frequency of the generated emf depends upon the wind turbine speed, excitation capacitance and load impedance (fig 8).

If load requires constant dc voltage, output of generators is converted into d.c. using chopper controlled rectifiers. Feedback system can be used to monitor and control to get desired performance.

V. ENERGY STORAGE

Wind power turbines have operational limitations over very high and very low speeds. When the power generated exceeds the demand, excess energy can be stored to be used at other times.

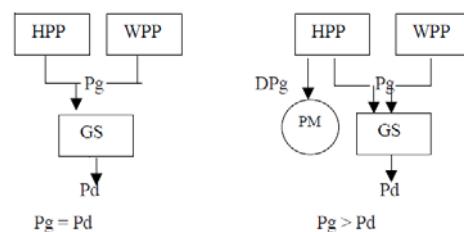


Fig 9. Water power storage system

- Excess energy can be conveniently stored in storage batteries in the form of chemical energy.
- Excess energy can also be stored in water power storage in the form of mechanical energy. Wind power plant (WPP) along with Hydroelectric power plant (HPP), when generated power (Pg) exceeds the power demand (Pd), helps to partly divert hydro power plant output to Pumping motor (PM) to pump water from an auxiliary reservoir at the bottom of the dam to main reservoir (fig 9).

- Excess energy can also be stored in the form of compressed air (fig 10).

When wind is not blowing, energy stored in compressed air could be used to drive wind turbine whose shaft would then drive a generator, thus supplying the needed power.

VI. SAFETY INTERLOCKS

Modern wind turbines are controlled by computers. If it shows any error in operational parameters, then wind turbine is stopped.

Emergency stop – During unfavorable conditions for wind turbines, it can be immediately stopped using emergency stop.

Wind velocity is measured and if gusts of wind are too strong or if the average speed is too high, wind turbine is stopped.

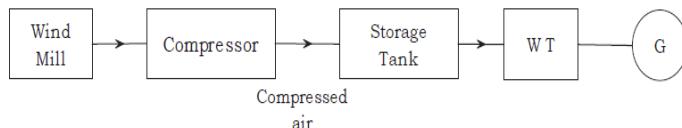


Fig 10. Compressed air storage system

To prevent rotor from racing, two revolution counters are mounted on the shaft. If wind turbine speed exceeds 24 rpm, it activates the emergency stop system.

If the wind turbine speed exceeds 28 rpm, a parachute attached to the blade tip is pulled out and thereby speed of the wind turbine decreases.

The three blades and wind turbine cap are grounded through lightning rods to protect them from lightning.

VII. CONCLUSION

The new mantra of the 21st century is sustainable development, which means that the local population should be able to absorb the development of a country or region. The

people should be financially, mentally and physically able to support the improvement in the quality of their lives. We want the entire population to have access to uninterrupted supply of electricity. This puts a huge burden on the limited fossil fuel resources. The benefits of using wind power over other resources lies in its minimum operational cost.

Depending on field of applications, various schemes can be adopted to get optimum output. Various option of storage facility makes it versatile source of energy. Modern turbines are totally controlled by computers that are totally safe.

Since wind is clean source of energy, the power conversion does not pose any environmental hazard.

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